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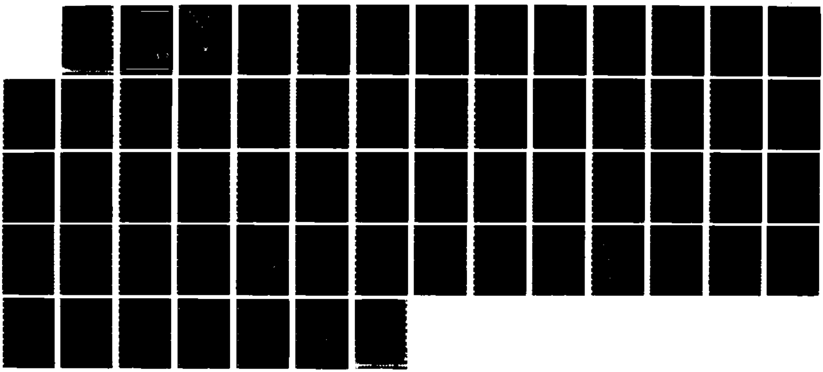

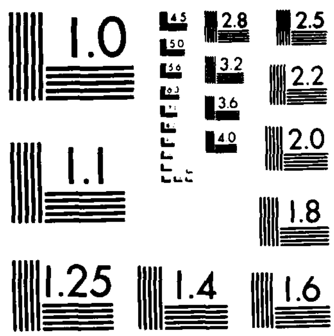

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VIENNA, VIRGINIA 22180

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DSCS NETWORK PERFORMANCE SOFTWARE (DNPS)

FINAL REPORT
November 1986

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CENTER FOR COMMAND AND CONTROL, AND COMMUNICATIONS SYSTEMS (C^4S)

" EXCELLENCE IN C^3 SYSTEMS FOR NATIONAL DEFENSE"

DSCS NETWORK PERFORMANCE SOFTWARE (DNPS)

FINAL REPORT
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DEFENSE COMMUNICATIONS AGENCY

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CHAPTER 1
INTRODUCTION

1.1 PURPOSE

This report documents the results of software enhancement and version release test support for the DSCS Network Performance Software (DNPS). This effort was addressed through three subtasks.

Subtask A: Requirements Analysis Development and Test

The purpose of this subtask was to analyze software/hardware change requirements resulting from either operational utilization of the DSCS Operational Control System (DOCS) resources or the evolutionary development of the control system.

Subtask B: Version Release Test Support

The purpose of this subtask was to support version release tests for the DNPS software in order to ensure that no major software logical errors or engineering modeling errors were introduced during the upgrade from one software version to another.

Subtask C: Integration of Multiple Beam Antenna (MBA) Resource Allocator

The purpose of this subtask was to refine the MBA allocation algorithm developed under the previous year's tasking to test the algorithm and to integrate the algorithm into the DNPS software resident at the DCEC computer facility.

1.2 REPORT ORGANIZATION

Chapters 2, 3, and 4 of this report summarize the efforts on these subtasks. Detailed results are provided in the primary subtask reports previously delivered under this task [Refs. 2, 3, 4, and 5].

CHAPTER 2

SUBTASK A: REQUIREMENTS ANALYSIS, DEVELOPMENT, AND TEST

2.1 PURPOSE

The purpose of this subtask was to provide software development and test support for the DNPS based on potential computer hardware/software change requirements identified as a result of either operational utilization of the DOCS resources or the evolving development of the DSCS control system. These requirements were to be analyzed, modifications recommended to the software/hardware (and/or new software/hardware recommended), and the changes implemented and tested.

2.2 SUMMARY OF RESULTS

This subtask was not activated. At the request of the COR (L. Krebs), funds for this subtask were directed to provide enhanced support for subtasks B and C.

CHAPTER 3

SUBTASK B: VERSION RELEASE TEST SUPPORT

3.1 PURPOSE

This test report documents results of the DNPS validation and verification testing effort. This testing is part of the continuing support provided by M/A-COM Government Systems, Inc., to the Defense Communications Engineering Center (DCEC).

The testing effort focused on three areas:

1. Comparison of test scenarios
2. Comparison of version test results
3. Identification of procedural problems.

The first area refers to the ability of DNPS to run the same (or nearly the same) test scenarios as the previous version software. This is important if accurate comparisons between versions are to be made. The second area concerns the key question to be answered by this test effort: will the new version software produce the same results as previous version software? Finally, any procedural difficulties and/or software anomalies encountered were documented in the form of software user reports (SURs). These SURs were delivered as generated and are listed in References 1, 2, and 3.

In all, three versions of DNPS were tested:

- DNPS Version 3.1
- DNPS Version 3.2
- DNPS Version 4.0

The following subsections summarize the test methodology and the results obtained.

3.2 TEST METHODOLOGY AND MEASUREMENT CRITERIA

The overall test methodology is shown in Figure 3-1. M/A-COM began by verifying that the static testing on-line data base was consistent between DNPS versions. This data base contains information such as satellite data (e.g., latitude/longitude, channel, EIRP) and modem data (e.g., type, P_b vs. E_b/N_o). Next, three test scenarios were run and results were gathered both for the current and new versions DNPS. These resuls were analyzed to determine how closely the new version results matched the current version results. Finally, any large discrepancies were noted and, where possible, traced to a software module or routine.

In the course of testing, software logical and procedural errors were noted and SURs were generated. These SURs are discussed in References 1, 2, 3.

The three text scenarios were designed to exercise different options of the software:

Test Scenario 01 tests the ECCM adaption software where there is a single user group defined, with all users and circuits of the same priority but with differing data rates.

Test Scenario 02 tests the ECCM adaption software for multiple user groups and priorities with differing data rates on the individual links.

The third scenario, the 'NEW USER TEST' scenario tests the network performance software and output generation software without the need for ECCM adaption. In other words, all traffic for this scenario was designed to be supportable without adapting the MBA or constraining the data rate. This ability to test the software for continuity of output was especially important for the DNBS 2.1/3.1 tests as Version 2.1

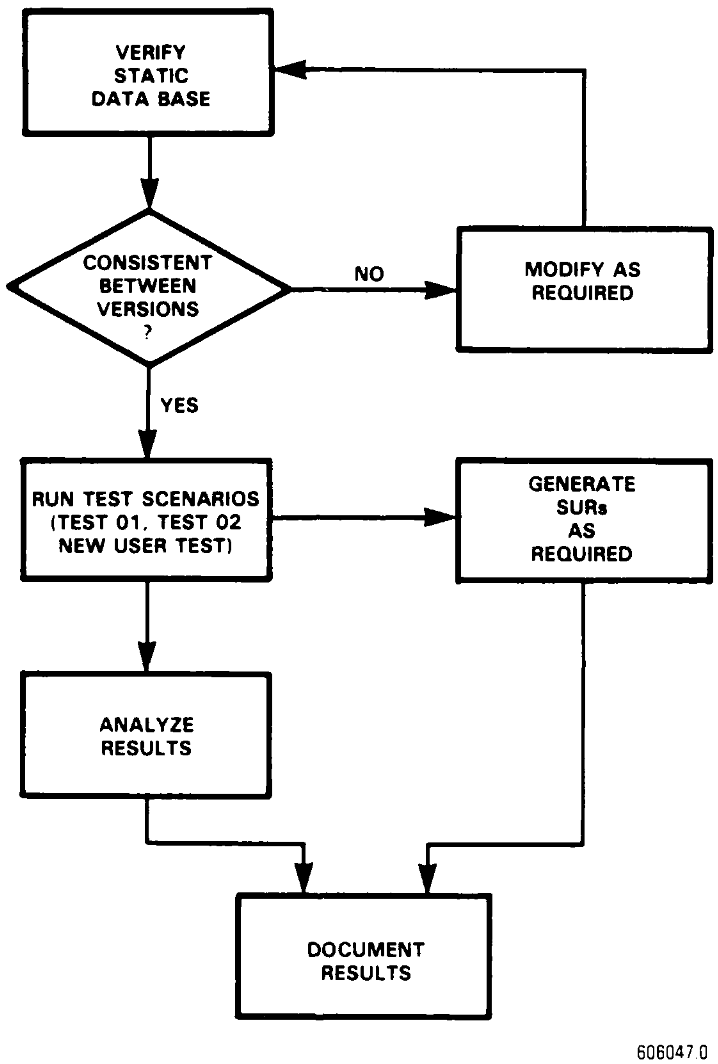

Figure 3-1. Test Methodology

did not contain the ECCM adaption software. Thus, the only true comparison to be made for this version release (3.1) was through the 'NEW USER TEST' scenario.

Details on all three scenarios can be found in Reference 1.

For the adaption subsystem runs, a tie breaker mode was employed. When a traffic network is not fully supportable, the breaker criteria are used to determine which links should be eliminated, reduced in data rate, etc.

When traffic elements are adapted into the network and two links have equal adaption criteria, the adaption algorithm needs a mechanism to determine which data elements to consider first. This mechanism is the "Data Rate Tie Breaker." Should all other adaption criteria be equal, the data rate requested by the traffic elements is used to determine which element should be selected (i.e., High - choose higher data rate). If data rates are the same, the final selection mechanism is simply the sequential order of the elements in the data base.

Each of the two "Test" scenarios was run twice; once with the tie breaker set to "High" and once with the tie breaker set to "Low."

3.3 TEST ASSUMPTION

In analyzing the results of the version comparison, it was assumed that variations of ± 0.01 dB were attributed to roundoff error. It was further assumed that variations of ± 0.5 dB were acceptable, given that +0.5 dB is equivalent to a 12 percent error and -0.5 dB equivalent to an 11 percent error (1 - .89).

When the results of the two adaptation cases were compared (Test 01 and Test 02), both modes of the adaptation tie breaker were exercised.

When adaptation cases were compared, the total offered (uplink) load in kilobits per second versus the supported load was calculated and compared version to version. In addition, the total number of links offered versus percent supported were compared.

Due to large numbers of circuits present in the "new user test scenario," only ECCM circuits results were compared to keep within the projected effort for this subtask.

3.4 SUMMARY OF RESULTS

This section summarizes the results obtained for the three versions, the conclusions drawn, and the recommendations made as a result of the overall test effort.

3.4.1 DNPS Version 3.1 Test Results

M/A-COM completed Version 3.1 tests in January 1986, and detailed results of the test effort can be found in Reference 1. The baseline for comparison of test results was DNPS Version 2.1.

Test Scenario 01 Results

Test Scenario 01 included ECCM links, FH links, FDMA links, and a definition for a jammer. Critical circuit criteria flags were set to their default condition, and a single user group within this test scenario was defined as having a priority of "000002." Thus, after inclusion of the CCC, RCCC, and IET links, all ECCM data circuits were given an equal priority for inclusion in the network. FDMA links were given varying priorities from 4 through 14 and were unconstrained. Thus, under the current version of the software, FDMA links were not expected to be adapted into the network (i.e., they must be constrained). Details of this scenario can be found in

Reference 1. Data rates on the circuits within the ECCM links were varied in order to exercise the software. FDMA links were allocated among Channels 1, 2, 3, and 4. Modulation and coding types were also varied on the links, and a small number of FH links were also included for completeness. The adaption criteria were based solely on the circuit priority.

Test Scenario 01 was used to test DNPS Version 3.1 software for two cases: once with the tie breaker set at "High" and once with the tie breaker set at "Low."

Test Scenario 01 Analysis

Test Scenario 01 included several high data rate links (i.e., greater than 100 kbps) with the remaining links having data rates of 0.075 kbps or 1.1 kbps. Under the default data rate tie breaker of "high," many of the links with lower data rates were not successfully adapted. This network configuration is consistent with the adaption criteria and default adaption settings. Tables 3-1 and 3-2 present results for this scenario (Tie Breaker "high"). Of 114 elements, only 29 of the 95 ECCM elements were successfully adapted into the network (30.5 percent). As expected, none of the FDMA traffic elements were adapted into the network because FDMA links must be "constrained" to be included in the network. Overall, 29 of 114 elements were not adapted into the network, or only 25.44 percent of the total.

In terms of throughput, only 1117.5 kbps of the offered uplink 3137.775 kbps was supported on Channel 1, and none of the FDMA links were supported. This represents a throughput reduction of 64.4 percent (1-carried/offered).

The scenario was run again using the same steps as documented in Reference 1; however, the tie breaker was set at "low." In this second run through adaption, the resulting

network configuration is again consistent with the adaption criteria and tie breaker selected. That is, the adaption process selected the lower data rate links at tie breaker points, and the resulting network included lower data rate links and rejected the unsupportable high data rate links.

Table 3-1. Version 3.1, Tie Breaker "High," Scenario 01

	ECCM	FDMA	TOTAL
Total No. of Traffic Elements	95	19	114
Total No. of Elements Adapted in	29	0	29
Offered Uplink Load (kbps)	3137.775	1023.55	4161.325
Downlink Carried Load (kbps)	1117.5	0	1023.55

Table 3-2. Version 3.1, *Tie Breaker* "Low," *Scenario* 01

	ECCM	FDMA	TOTAL
Total No. of Traffic Elements	95	19	114
Total No. of Elements Adapted	91*	0	91*
Uplink Offered Load (kbps)	3137.775	1203.55	4161.325
Downlink Carriers Load (kbps)	1037.7	0	1037.7

*Includes two elements at 0.00 kbps.

Table 3-2 presents specific results for this scenario, with the tie breaker set at "low." Of a total of 114 traffic elements, 91 were adapted into the network or 79.82 percent. Of the ECCM elements, 91 of 95 elements were adapted, or 95.79 percent. However, as expected, the high data rate links were

dropped in favor of the low data rate links. Of the 3137.775 kbps offered on Channel 1, 1037.7 kbps were supported, a decrease of 66.93 percent, and all of the supported links were "low" data rate links (less than 100 kbps).

There was, however, one anomaly uncovered during these runs. Two ECCM elements (ECCM 09 and ECCM 10) were listed in the ECCM link parameter summary as having an active status (i.e., "On"); however, their data rates were listed as 0.00 bps. This is evidently a software problem, perhaps a rounding error and bears further investigation. An SUR was issued and can be found in Reference 2.

If these elements are removed from the statistics, only 89 of 95 links were adapted, or 93.68 percent.

For the FDMA traffic elements, none of the 19 FDMA traffic elements were adapted as expected, based on the adaption criteria established.

In addition, an improvement in processing time required was noted using the tie breaker set at "low." The run times are as follows:[1]

- Data Rate Tie Breaker "high" - 36 CPU minutes
- Data Rate Tie Breaker "low" - 29 CPU minutes.

Note that these run times reflect process time spent in the CPU. The times do not include the login time required to perform all the required steps prior to adaption and the running of this scenario through the Adaption subsystem.

---

[1]Run times also include report generation and use of other subsystems of DNPS.

Test Scenario 02 Description

Scenario 02 included definitions for ECCM links and FDMA links. Different user groups were defined, and prioritization of these groups varied from "000000" to "999998." Adaption criteria were also established based on data rate constraints, geographic locations, and user classification (e.g., SVGC).[2] Details of this scenario can be found in Reference 1. Link definitions in the scenario provided traffic for channels 1, 2, 3, and 4. Table 4-1 gives specific test steps. As with Scenario 01, the two "Tie Breaker" modes were exercised, and results obtained using Version 3.1 of DNPS were analyzed.

Test Scenario 02 Analysis

Test Scenario 02 was defined with link data rates from 100 to 1000 kbps. Using the default settings of the Adaption Subsystem (including tie breaker set at "high"), most of the links of lower data rates were unsupportable. This is consistent with the options selected and with the design of the software. Table 3-3 summarizes the results obtained for Tie Breaker "high" of the 143 (ECCM plus FDMA) unconstrained traffic elements. Forty-two of the ECCM traffic elements were adapted into the network (29.4 percent). As expected, all were ECCM elements.

Thus, of the 126 ECCM elements, only 33.3 percent could be supported in this scenario. Out of a total uplink offered load of 2283 kbps, only 1013.875 kbps was supported, a reduction of 55.6 percent. On Channel 1, half of the FDMA links were supportable.

---

[2] A valid user class for this scenario.

Table 3-3. Version 3.1, Tie Breaker "High," Scenario 02

	ECCM	FDMA	TOTAL
No. of Traffic Elements	126	17	143
Total No. of Elements Adapted	42	0	42
Total Uplink Offered Load (kbps)	2283.0	1023.55	3306.55
Total Downlink Supported Load (kbps)	1013.875	0	1013.875

The network that was created using tie breaker set at "low" was consistent with the options selected (i.e., the links of large data rates could not be supported). Table 3-4 presents the detailed results of this scenario. Of the total 143 (ECCM plus FDMA) traffic elements, only 89 traffic elements were adapted. Of these 89, all were ECCM (Channel 1) traffic elements. Thus, of the 126 ECCM elements, 89 (or 70.6 percent) were adapted. Of a total uplink offered load of 2283 kbps, 281.8 kbps was supported, a reduction of 87.66 percent. On Channel 1, almost all of the high data rate links were unsupported.

Table 3-4. Version 3.1, Tie Breaker "Low," Scenario 02

	ECCM	FDMA	TOTAL
Total No. of Traffic Elements	126	17	143
Total No. of Elements Adapted	89	0	89
Total Uplink Offered Load (kbps)	2283.0	1023.55	3306.55
Total Downlink Supported Load (kbps)	281.8	0	281.8

The run times for this scenario were as follows:[3]

- Data Rate Tie Breaker "high" - 88 CPU minutes
- Data Rate Tie Breaker "low" - 51 CPU minutes.

A significant improvement in processing was noted using the tie breaker set at "low." Note that these run times reflect process time spent in the CPU. The times do not show the login time required to perform all the required steps prior to adaption and running this scenario through the Adaption subsystem.

As in Test Scenario 01, the adaption process in Test Scenario 02 did not provide any successfully adapted FDMA links. This is consistent with the adaption criteria established in the scenario definition.

New "User-Test" Scenario Description

The user-test scenario provides for verification of output of different versions of DOSS/DNPS software. This scenario was established as a feasibility study of traffic in Channel 1; although the scenario contains definitions for links in other channels, the scenario was primarily used for the evaluation of Channel 1 traffic. Unlike test scenario 01 and test scenario 02. The new user test scenario was chosen such that the adaption subsystem would not be required to develop a supportable network. Development of the latter scenario was necessary since Version 2.1 does not have ECCM adaption capabilities (i.e., no ENAM as in Version 3.1) and direct comparison of results between Versions 3.1 and 2.1 would not be possible using test scenarios 01 and 02.

---

[3]Run times also include report generation and use of other subsystems of DNPS.

Due to the large number of Channel 1 circuits in the new user scenario, it was not possible to analyze all links. Instead, 22 circuits were analyzed in detail along with an overall comparison of satellite and network parameters between software versions (2.1 and 3.1).

Analysis of Results

In this section, comparative analyses are presented and discrepancies between versions 2.1 and 3.1 are noted. A total of three major output report headings were analyzed in detail: Network Performance Subsystems Network Performance Summary, Network Performance Subsystem Satellite Analysis Summary, and the Network Performance Subsystem Network Performance Summary.[4]

The scenario definition and initialization subsystems were compared prior to detailed testing to ensure that each version was tested using the same scenario (i.e., terminal, satellite, and same user parameters). Detailed results of this scenario can be found in Appendix C.

Network Performance Summary

Results for the Network Performance Summary are given in Table 3-5 for "User-Test" scenario. For the Channel 1 users, there is no appreciable difference in Version 3.1 results over Version 2.1 results; the Channel 1 backoff[5] matches exactly from version to version, and the channel gain is within 0.02 dB, well within the round-off error expected. The same is true of the channel 2 and 5 results; in both cases, results are identical between versions 2.1 and 3.1

[4]The Adaption subsystem was not exercised for these runs.
[5]Backoff power (in dB) from saturated spacecraft high power amplification.

Table 3-5. Network Performance Summary

PARAMETER	V2.1	V3.1	DELTA*
Channel 1 Backoff (dB)	0.01	0.01	0
2	3.01	3.01	0
3	1.55	1.68	+0.13
4	1.59	2.65	+1.06
5	1.55	1.55	0
6	1.55	2.40	+0.85
Channel 1 Gain (dB)	105.93	105.95	+0.02
2	117.90	117.90	0.0
3	105.15	105.27	+.12
4	105.80	106.28	+0.48
5	105.65	105.65	0
6	112.25	112.73	+0.48

*V3.1-V2.1.

The results for Channel 3 are not quite as good; backoff is somewhat higher (.13 dB) as is channel gain (.12 dB) for Version 3.1 as compared to Version 2.1, although still within acceptable (± 0.5 dB) limits.

Channels 4 and 6 results show a good deal of variation from version 2.1 to 3.1; 1.06 and 0.85 dB respectively for backoff and 0.48 dB each for channel gain.

One explanation for the above differences is that the calculation of IM products was done for Version 2.1 tests, and

was not done for Version 3.1 tests. This probably accounts for the somewhat larger backoffs present in Version 3.1 results. Since the intermod products were not present, and power sharing was linear, a smaller fraction of total power was necessary to achieve the required link margins. (As the IM calculation algorithm may be changed in the near future, these runs were not repeated.)

Satellite Analysis Summary

The Satellite Analysis Summary results are given in Table 3-6. As with the Network Performance Summary, channels 1, 2, and 5 results for Version 3.1 are all within .01 dB of Version 2.1 results. Again, due to the addition of IM products options, channels 3, 4, and 6 satellite results in Version 3.1 differ from Version 2.1 results in a similar manner as discussed in paragraph 5.2.1 on Network Performance Summary.

Given the total power present in the downlink channel, it was concluded that this is due to user selection of the option to exclude IM power calculations in the test of Version 3.1.

Link Performance Summary

This section presents version 2.1 and 3.1 link performance summary results. Due to the large number of links in Channel 1 (46 SSMA), and the fact that four links are established for each SSMA user terminal (RL, RN, CCC, and USER), all links were not analyzed. Instead, 22 links were chosen at random for comparison.

Table 3-7 gives high and low (greatest and smallest) deviations from Version 2.1 to 3.1.

Table 3-6. Satellite Analysis Summary

Channel Number	1			2			3		
	V2.1	V3.1	Delta	V2.1	V3.1	Delta	V2.1	V3.1	Delta
Input Power (dBM)									
FDMA	-	-	-	-76.97	-76.97	0	-68.24	-68.50	-0.26
SSMA	-69.39	-69.5	+0.11	-	-	-	-	-	-
FH	-97.56	-	-	-	-	-	-	-	-
Noise	-90.46	-90.46	0	-	-	-	-	-	-
Jammer	-62.72	-62.72	0	-	-	-	-	-	-
Subnets	-	-	-	-	-	-	-	-	-
TOTAL	-61.86	-61.88	-0.02	-76.78	-76.78	0	-68.24	-68.50	-0.26
Output Power (dBM)									
FDMA	-	-	-	40.90	40.91	-0.01	36.71	36.60	+0.11
SSMA	32.13	31.99	-0.14	-	-	-	-	-	-
FH	3.98	-	-	-	-	-	-	-	-
Noise	15.47	15.49	+0.02	27.44	27.44	0	16.20	16.32	+0.12
Jammer	43.50	43.52	+0.02	-	-	-	-	-	-
IM	32.48	-	-	19.41	-	19.41	24.38	-	24.38
Subnets	-	-	-	-	-	-	-	-	-
TOTAL	44.07	44.07	0	41.12	41.12	0	36.95	36.82	-0.13
Max Pwr Available	44.08	44.08	0	44.13	44.13	0	38.50	38.50	0
% of 3-dB Pwr Used	199.52	199.52	0	100.01	100.01	0	140.12	135.75	-4.37
Backoff (dB)	0.01	0.01	0	3.01	3.01	0	1.55	1.68	+0.13
Channel Gain (dB)	105.93	105.95	+0.02	117.90	117.90	0	105.80	105.27	-0.53
% Bandwidth Used	0	0	0	5.0	5.0	0	19.63	19.63	0

Table 3-6. Satellite Analysis Summary (Continued)

Channel Number	4			5			6		
	V2.1	V3.1	Delta	V2.1	V3.1	Delta	V2.1	V3.1	Delta
Input Power (dBM)									
FDMA	-68.71	-70.26	-1.55	-68.58	-68.58	0	-74.79	-74.16	-1.37
SSMA	-	-	-	-	-	-	-	-	-
FH	-	-	-	-	-	-	-	-	-
Noise	-90.59	-90.59	0	-90.46	-90.46	0	-91.26	-91.26	0
Jammer	-	-	-	-	-	-	-	-	-
Subnets	-	-	-	-	-	-	-	-	-
TOTAL	-68.68	-70.22	-1.54	-68.55	-68.55	0	-74.69	-76.03	-1.34
Output Power (dBM)									
FDMA	+36.89	35.95	-0.94	36.87	36.87	0	37.26	36.48	-0.78
SSMA	-	-	-	-	-	-	-	-	-
FH	-	-	-	-	-	-	-	-	-
Noise	+15.21	15.69	-0.48	15.19	15.19	0	21.0	21.47	+0.47
Jammer	-	-	-	-	-	-	-	-	-
IM	24.35	-	24.35	24.63	-	24.63	24.98	-	24.98
Subnets	-	-	-	-	-	-	-	-	-
TOTAL	37.12	36.06	-1.06	37.10	37.10	0	37.56	36.70	-0.86
Max Pwr Available	38.71	38.71	0	38.65	38.65	0	39.11	39.11	0
% of 3-dB Pwr Used	138.55	108.64	-29.91	140.12	140.12	0	140.12	114.90	-25.22
Backoff (dB)	1.59	2.65	1.06	1.55	1.55	0	1.55	2.41	-0.86
Channel Gain (dB)	105.80	106.28	-0.48	105.05	105.05	0	112.25	112.73	- 0.48
% Bandwidth Used	25.67	25.67	0	10.70	10.70	0	13.68	13.68	0

Table 3-7. Measurement Deviation Summary for Channel One Link Performance

	TRANSMIT POWER (dBM)	TERMINAL DELTA (dB)	U.L. DIRECTED GAIN (dBM)	SIGNAL POWER (dBM)	% CH POWER	D.L. DIRECTED GAIN (dB)	C/kT PRE (dB)	MARGIN PRE (dB)
High Delta	-0.21	-2.25	0	+0.23	+0.01	0	+0.37	+0.31
Low Delta	0	+0.17	0	+0.01	0	0	0	+0.1

3.4.2 DNPS Version 3.2 Test Results

Beginning with Version 3.2 testing, a file comparison utility was used to compare the difference in values calculated in the network performance summary report. The reports were analyzed twice; once before adaption and once after adaption had been completed.

In addition, this utility was used to verify the scenarios used to determine that the data migration utility software performed its function without corrupting the data base. Both the system and user data bases were successfully migrated to the new operating system without any errors being detected.

Test Scenario 01 Results

Test Scenario 01 was run again for DNPS versions 3.1 and 3.2. No significant differences were noted in the calculations either before or after adaption, with the exception of an anomolous calculation of intermodulation products in Channel 4 [Ref. 2].

Adaption Results

Test Scenario 01 included several higher data rate links (100 kbps) with the links of interest having data rates of from 1.1 kbps to 0.075 kbps. The total uplink load offered to the network was 3137 kbps (including CCC IET, and RCCC links).

Under the default tie breaker of "high," many of the low data rate links were not adapted into the network. This is consistent with the adaptation criteria selected. Table 3-8 summarizes the results in terms of offered versus carried uplink load (kbps) and number of downlink circuits supported for both versions 3.1 and 3.2. The total supported uplink load

was 1023. 55 kbps and of the 95 ECCM traffic elements, 22 were supported in both versions 3.1 and 3.2.

Table 3-8. Test Scenario 01: Tie Breaker High

	V3.1	V3.2	Delta
Uplink Offered Load (kbps)	3137.775	3137.775	0
Uplink Supported Load (kbps)	1023.55	1023.55	0
Downlink Traffic Elements Offered	95 ECCM	95 ECCM	0
Downlink Traffic Elements Supported	22 ECCM	22 ECCM	0

The scenario was run again with the data rate tie breaker set to "low." Results are summarized in Table 3-9. The total supported uplink load was 131.77 kbps for versions 3.1 and 3.2. The lower data rate links were selected over the higher data rate links, as was expected.

Table 3-9. Test Scenario 01: Tie Breaker Low

	V3.1	V3.2	Delta
Uplink Offered Load (kbps)	3137.775	3137.775	0
Uplink Supported Load (kbps)	137.775	137.775	0
Downlink Traffic Elements Offered	95 ECCM	95 ECCM	0
Downlink Traffic Elements Supported	93 ECCM	93 ECCM	0

Based on the results obtained in both the "Network Performance" and "Adaptation" states, it was concluded that the DNPS Version 3.2 was producing acceptable results for Scenario 01.

Version 3.2 results closely agree with Version 3.1 results, and no major discrepancies were noted in the execution of the software. The tie breaker high results compare favorably with those obtained in version 2.1/3.1 testing, where 1117.5 kbps of throughput was achievable. However, the tie breaker "low" results, while supporting a similar number of traffic elements, are off an order of magnitude from the version 2.1/3.1 results. This result requires further investigation.

Test Scenario 02

Version Comparison Results

The FILECOMP utility was again used to compare results between versions 3.1 and 3.2. As with the previous test scenario, comparisons were made in both the network performance state and the adaptation state. Differences are summarized in Reference 1. All results were within acceptable limits ($\pm$0.5 dB) and most results were within $\pm$0.2 dB.

Adatation Results

This section discusses the results of the two adaptative runs made: tie breaker "high" and tie breaker "low." As with Test Scenario 01, results are presented both in terms of offered versus carried load (uplink) and in terms of total number of traffic elements supported. The total load offered to the network for Test Scenario 02 was 2283 kbps, spread over 46 links. These links included 8 RTACS links, 5 SVGC links, and 10 "standard" ECCM links as well as CCC, IET, and RCCC links.

For the tie breaker "high" runs (Table 3-10), two ECCM links were dropped: ECCM 0901 and ECCM 1001. Both were 1 Mbps links, and thus the total carried load dropped to 283 kbps for

the ECCM links. As expected, none of the FDMA links were supported.

Table 3-10. Tie Breaker "High" Results

	V3.1	V3.2	Delta
Uplink Offered Load (kbps)	2283.0	2283.0	0
Uplink Carried Load (kbps)	283.0	283.0	0
Downlink Offered ECCM Traffic Elements	126	126	0
Downlink Carried ECCM Traffic Elements	124	124	0

One possible explanation may lie in the manner in which traffic elements are sorted for adaptation into the network. The sort software was modified in this latest version, and traffic elements were presented for adaptation into the network in a different order from version 2.1/3.1 testing. Because the adaptation order changed, the adaptation results may have changed. Another possible (although unlikely) explanation may be in the way that FDMA uses are specified in the scenario.

For the tie breaker "low" runs (Table 3-11), the same two links were dropped in both versions 3.1 and 3.2.

These results are somewhat unexpected. It is expected that the tie breaker high runs to produce results which favor the high data rate links. A further check of the Version 3.1 results, which were obtained in December (V2.1/3.1; Reference 1), shows a completely differently result (Table 3-12). Resolution of this problem requires further investigation. An SUR was issued for this anomolie.

Table 3-11. Tie Breaker "Low" Results

	V3.1	V3.2	Delta
Uplink Offered Load (kbps)	2283.0	2283.0	0
Uplink Carried Load (kbps)	283.0	283.0	0
Downlink Offered ECCM Traffic Elements	126	126	0
Downlink Carried ECCM Traffic Elements	124	124	0

Table 3-12. Version 2.1/3.1 Results

	Tie "High"	Tie "Low"
Total ECCM Traffic Elements	126	126
Total Supported ECCM Elements	29	91

Conclusions

For the scenarios tested, the DNPS software produced consistent results between versions 3.1 and 3.2; however, the one discrepancy mentioned above requires further investigation. In addition, the results for the tie breaker "low" are comparable to those obtained in Version 2.1/3.1 testing, where a total throughput of 281.8 kbps was observed for the ECCM (Channel 1) circuits.

User Test Scenario

The user test scenario was used to verify the satellite analysis, allocation, and network performance subsystems of DNPS. This scenario was developed by DCEC as a feasibility

study for Channel 1 traffic. Because of the large number of links present, only the ECCM traffic was analyzed (as in Reference 1).

Scenario Description

The user test scenario consists of 46 ECCM links and 157 FDMA links that use 100 terminals. In addition, the scenario has 7 jammers and 2 FH links. The satellite used for the defined network was the Atlantic DSCS III (IRON 6451). This scenario was constructed to avoid adaptation. A detailed description can be found in Reference 1.

Version Comparison Results

The differences between Version 3.1 and Version 3.2 of DNPS follow. Note that all values listed are relative to DOSS/DNPS Version 3.2.

- Network Performance Summary

  No differences were noted in any calculation between the two versions of the software.

- Link Performance Summary

  All values listed are relative to Version 3.2 of DNPS. High, low, and average deviations are given in dB.

Link Type	Terminal Delta (dB)
CCC Average	-.16
IET Average	-.16
RL1/RN1 High	+.83
RL1/RN1 Low	-1.53
RL1/RN1 Average	-.2858
ECCM High	+.83
ECCM Low	-1.53
ECCM Average	-.6384

- Terminal/Jammer Directive Gain Summary

  No differences were noted (in any calculation) between versions of the software.

- Satellite Analysis Summary

  No differences were noted (in any calculation) between versions of the software.

Based on the above results, the new user test scenario was verified in Version 3.2 of the DNPS. Although the terminal Delta power deviation was somewhat high in two cases (-1.53 dB), the overall performance of the network was verified to be within the tolerances discussed. It is not clear why the terminal data power measurements were off by such a large amount (1.53 dB). This problem needs further investigaton, because it was also observed (but not resolved) during Version 2.1/3.1 testing.

3.4.3 DNPS Version 4.0

For this particular release, only one "engineering" change was made to the software: the major emphasis of this release was the modification of software report generator logic and

run-time logic. It was agreed that it would not be necessary to perform a complete version comparison test (as was done with previous releases).

Instead, the system software was checked for logical errors, and results were checked in an engineering sense only for these modules affected by the recent change (i.e., the PN Code Rate Change).

SURs were generated as appropriate and can be found in Appendix A of Reference 3.

3.4.3.1 Summary of Results

This version of software performed as expected utilizing established scenario files used in past testing efforts. The significant change in this version (at the DCEC) was a new VAX VMS operating system, an 11/730 computer to replace the PDP-11, and new display devices (i.e., Tektronix 4107/4125 printer and plotters). There were no gross errors noted in this release of the software despite the major changes in hardware and system software.

Software Logic

During the testing effort, 10 SURs were subsequently generated and submitted (Appendix A of Reference 3). The most significant of these describe a change that resulted when a user aborts adaption and enters the Network Performance Subsystem. If the user enters the "Margin Leveling" subsystem, the software does not display the expected menu and seems to be executing code. While this in itself is not significant, any documented changes to the software should not have created this anomaly. Regression testing of Version 3.2 shows that this anomaly is unique to Version 4.0.

Another anomaly of the software present in both versions 3.2 and 4.0 dealt with the Adaption subsystem. When the user aborts an adaption run and returns to the top level of DNPS, the system state is "Adaption" when it should be "Network Performance." When the user returns to the top-level menu of DNPS, through normal termination, the adaption software has tried to include all links into the network, the system state is set to "Network Performance" when it should be "Adaption." Logically, the terminology of the system states seems to be reversed for the cases noted.

Display Algorithms

Because of Tempest noncompliance of the 4125 display device (at the time of testing at DCEC), output to this device could not be fully tested. Utilizing the DCMTEST. EXE and the 4014 Tektronix softcopy display device, most aspects of the display algorithms were tested. Certain anomalies existed in the automatic display of the Adaption Ranking Report. While the user could automatically display the report at a predefined step in the creation of the network, only page one (of a multipage report) was being displayed. This limitation of this change in the software severely restricts the usefulness of the change.

Engineering Changes

The only engineering change made to this version involved the calculation of the bandwidth of an ECCM Link (implementation of SUR457). In Version 4.0 the ECCM link bandwidth was set to be twice the chip rate. Initial results of this change showed an error in the Network Performance and Link Performance Reports: link origins, which were being met in Version 3.2, were not easily met in Version 4.0 for the same scenarios.

The resulting investigation of these anomalies by Stanford Telecommunications Inc. (STI) showed that the software was not correctly modified for this change. A follow-up (emergency patch) release was distributed and further testing showed the corrected implementation to perform as intended. It has been subsequently decided to remove this change and delay its implementation to a future release.

3.5 RECOMMENDATIONS AND CONCLUSIONS

3.5.1 Conclusions

In general, the DNPS software has produced consistent results from version to version in terms of power levels and margins in the Network Performance/Allocation Subsystems.

However, a number of anomalous conditions were noted in the Adaption subsystem, particularly in the Version 3.1/3.2 test results. These anomalous conditions are described in References 1, 2, and 3, and should be investigated and accounted for in order to maintain user confidence in the software.

3.5.2 Recommendations

Automated Testing

Because DOSS/DNPS is a network-driven software package, it is possible to automate the testing effort. This automation could be as simple as using data files to emulate the user input that would be transmitted (via DECNET) to DOSS/DNPS. Additional methods exist to automate this process, such as modifying the local networking node emulator (DCMTEST.EXE). These modifications could include the following:

1. Interrupt Driver. A interrupt driver could be installed in DCMTEST.EXE to provide a method to exit DOSS/DNPS. This method would also allow an orderly reentry into DOSS/DNPS.

2. User Emulation. Data files could be used to emulate user interaction with DOSS/DNPS.

3. Interactive File Examination. DOSS/DNPS reports could be reviewed (excluding plotter output) interactively at the VT100 terminal.

Additional methods of automated testing should be explored.

It is recommended that a set of scenarios be developed which are specifically designed to test the new/improved features of the release in question. For example, a set of Version 4.0 scenarios might have been developed that tested the PN code rate versus bandwidth calculations during the SUR integration phase and the beta test phase.

In this manner, problems with the software can be surfaced and corrected before version release testing.

Ideally, these test procedures should be specified before any software is modified and should be developed independently of the new software. That is, a test or tests should be devised that evaluate the new software in a general sense, and in both a stand-alone (module) and fully integrated manner.

The file comparison utility FILECOMP.EXE could be used to aid in automated verification. This could be accomplished by establishing formalized procedures concerning data generated and the programs used. Additional methods of verification automation should be explored.

Additional Sceanrios

It is recommended that two additional scenarios be established. These are as follows:

1. Minimal Configuration Scenario. A scenario should be established that meets the minimum requirements for a user-defined scenario. This scenario would test the software for its ability to meet documented requirements for such scenario definitions. In addition, it would create an additional criterion for software testing and validation between versions of software.

2. Maximum Configuration Scenario. A scenario should be established that tests the software's ability to detect the maximum limits in scenario definitions. This scenario would also verify documentation of the software for such limits. In addition, this scenario would also benchmark the software in a "worst case" (maximum data definition) test.

Software Runtime Analysis

Methods to analyze the software using noninterfering means should be examined. This would involve the creation of a body of software that would accumulate software performance statistics. The accumulated data would aid DCA/DCEC personnel in making decisions concerning software modifications.

Man-Machine Interface (MMI) Baseline

It is recommended that the MMI of the software be verified in a future version to establish a baseline of known (MMI) problems and working (MMI) code.

Verify Modifications Made to Software Modules

When a module (i.e., a subroutine) is modified, it should be tested (and the testing procedures documented) prior to integration into the software system.

Module Testing

It is recommended that the software be tested by module (subroutine). This involves "desk checking" a specific module and then testing the specific module for integrity.

Module Extraction

It is recommended that some of the modules of DOSS/DNPS by used in other stand-alone programs. An example of this would be the Resource Allocation Software (RAS) COTRAN software. This software package calculates the Azimuth and Elevation angel, the satellite antenna, based on the earth terminal locations. It is possible to use this software package to calculate the latitude and longitude of a terminal based on the azimuth/elevation (or azimuth and elevation based on latitude and longitude). Module extraction would realize programs to support task-specific problems using existing software. In addition, this method provides a means to test specific modules of DOSS/DNPS.

CHAPTER 4

SUBTASK C: MULTIPLE BEAM ANTENNA ANALYSIS

This subtask was extended prior analyses to develop methods to improve the Multiple Beam Receive Antenna (MBR) Resource Allocator Algorithm for the DSCS III spacecraft. The proposed algorithm used a gradient technique to find the optimum beam-weights based on a functional minimization of the constrained Least Mean Square (LMS) error between desired and actual antenna gains.

4.1 DESCRIPTION OF THE MBR ALGORITHM

This section discusses a constrained LMS algorithm to select beam weights for an MBR antenna. The antenna will synthesize a desired antenna gain pattern that is specified by the magnitude response.

4.1.1 Description of the Solution Approach

It is useful to characterize the total response of an antenna both by magnitude and by phase responses over the field of view (FOV). However, since only directive gain is specified for each earth terminal, only the magnitude response is considered here.

Least Mean Square Error Criterion

The solution approach is an LMS fit to the desired directive gains of the MBR antenna. Such a solution has the form:

$$e^2 = \sum_{m=0}^{M-1} b_m [|d_m| - |g_m|]^2, \qquad (4\text{-}1)$$

where d_m is the desired; complex voltage gain; g_m is the resultant complex voltage gain; and b_m is a positive real constant indicating the relative importance of each point. Rewriting equation (4-1) in vector form, the expression becomes:

$$e^2 = (|\underline{D}| - |\underline{G}|)^T B (|\underline{D}| - |\underline{G}|), \tag{4-2}$$

where $\underline{D}$ is the Mx1 desired; complex voltage gain vector; $\underline{G}$ is the Mx1 resultant, complex voltage gain vector; and B is an MxM positive real diagonal weighting matrix. The symbol T denotes the transpose of a vector or matrix, and M is the number of specified terminal locations.

The resultant gain G is a function of the ambient pattern of the antenna and the beam weights. The ambient antenna pattern is modelled using the singlet antenna data, which gives the gain for each of the antenna elements at specified locations on the earth's surface. A singlet data matrix may be constructed for different areas of interest on the earth's surface, and the matrix has the form:

$$A = [x_{m,n} + y_{m,n}]_{m,n} \tag{4-3}$$

where m = azimuth/elevation coordinate index; m = 1, 2, ..., M
n = singlet beam index; n = 1, 2, ..., N.

That is, each of the M rows of A correspond to a specific azimuth/elevation coordinate point within the area of interest, and each of the N columns correspond to a particular singlet beam. For DSCS III spacecraft, the number of singlet beams, N, is 61, and M may vary from one point to full coverage of 8281 points*.

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*Full coverage consists of $\pm 9^\circ$ azimuth and elevation, with 0.2° granularity, fromthe subsatellite point.

The resultant gain is given by the vector expression:

$$\underline{G} = A\ \underline{W} \qquad (4\text{-}4)$$

where $\underline{G}$ is the Mx1 resultant, complex voltage gain vector; A is a MxN complex matrix of singlet data; and $\underline{W}$ is Nx1 the complex beam weight vector.

For typical scenarios, the gains at terminal locations are specified in decibels, not volts. To convert the resultant voltage gain to directive gain, the following expression is used:

$$(G)_{dB} = 20 \log_{10}[|\underline{G}|] \qquad (4\text{-}5)$$

where G is the complex voltage gain defined in equation (4-4).

Substituting equation (4-4) in equation (4-2), the expression becomes:

$$e^2 = (|\underline{D}| - |A\ \underline{W}|)^T B(|\underline{D}| - |A\ \underline{W}|). \qquad (4\text{-}6)$$

The problem is to find the beam weight vector, $\underline{W}$, that minimizes e^2. There are several computer packages, such as the International Mathematics and Statistical Library (IMSL), containing gradient optimization routines to perform the minimization. The IMSL package uses a gradient technique, called the Davidon-Fletcher-Powell (DFP) algorithm to functional minimization. The DFP algorithm uses the following iterative formula to perform the minimization.

$$\underline{W}_{k+1} = \underline{W}_k - a_k H_k \underline{g}_k$$

where

$\underline{W}_{k+1}$ = the new value of the vector $\underline{W}$

$\underline{W}_k$ = the previous value of the vector $\underline{W}$

a_k = constant

H_k = a matrix

g_k = the gradient of the function to be minimize.

The program performs iterations until some acceptance criterion is met; e.g., a certain number of iterations are performed or the difference between new and old values is less than a given tolerance.

Constrained LMS Criterion

Although the LMS method may be used to find a solution, there is an additional constraint on the solution vector: its norm must equal one.

$$\| \underline{W} \| = 1, \tag{4-7}$$

or,

$$\underline{W}^t \underline{W} = 1. \tag{4-8}$$

This constraint arises from the fact that the antenna of interest is a passive device, and thus, its gain must be less than or equal to unity.

A standard way to include a constraint in the solution is to compose a cost function of not only the LMS cost function e^2 , but also a penalty function, P, to address the constraint. Such a cost function has the form:

$$C = e^2 + kP. \tag{4-9}$$

The k is a weighting constant for the penalty function. In this case, the penalty function may be expressed as the squared difference between the actual norm of the beam weight

vector and the required norm. The new cost function is given by:

$$C = e^2 + k[1 - \|\underline{W}\|]^2 \tag{4-10}$$

The same IMSL optimization routine may be used as with the unconstrained case to find the beam weight vector, $\underline{W}$, that minimizes the cost function given by equation (4-10).

Pattern Control via the Weighting Matrix B

One of the features of the proposed algorithm is that it allows different weighting, or emphasis, via the B-matrix of equation (4-6). In equation (4-6), the B matrix contains the information about weighting for each terminal. Weighting may be applied in different ways. User locations in a network or interferer locations may have different weight values assigned, based on their relative importance. The weight elements of the B matrix may also be used to emphasize a particular terminal or set of terminals to increase the antenna discrimination in a particular region in the FOV. This is especially useful in scenarios where desired and interfering terminals are in close proximity. Thus, based upon the selection of different weighting (or emphasis) matrices B_1, B_2, ..., the LMS algorithm will produce different antenna beam weight vectors W_1, W_2, ...

4.2 TEST SCENARIOS

Although an infinite variety of test scenarios can be used to demonstrate the performance of an MBA algorithm, a single, relatively simple, generic scenario was used to demonstrate the performance for critical applications and to show the limiting performance cases. All of the examples considered in this report were derived from the same basic scenaro with terminal locations given in Figure 4-1. The locations of interferers

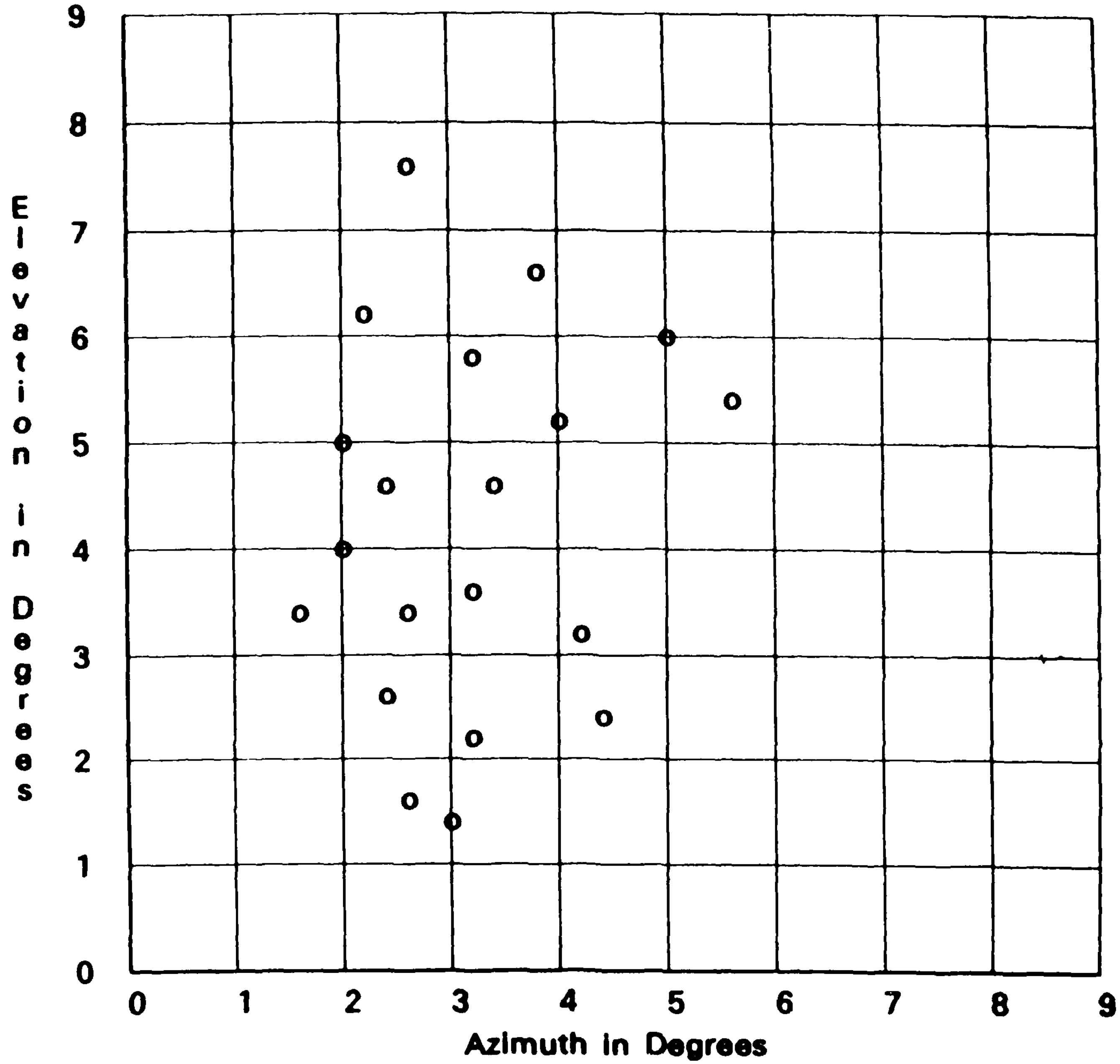

Figure 4-1. Terminal Locations for the Basic Scenario

are not shown because these locations depend upon the specific example. Also, for simplicity, the directive gain to all the desired terminals were chosen to be equal, but the gain varied from one example to another. The gain was arbitrarily chosen to be either 20 or 25 dBi -- typical uplink gain values for DSCS users. Likewise, the required discrimination between the desired terminals and interferers depends upon the particular example and is specified to be either 40 or 50 dB. The values of the required gain and discrimination are not based on actual requirements, but are intended to reflect typical scenarios and the capabilities of the MBR antenna.

4.3 INTERFERER LOCATION

The first set of examples demonstrates the effect of interferer location on the shape of the null. To perform the experiment, the basic scenario (Figure 4-1) was used with 20-dBi direction gains. A single interferer with a desired gain of -20 dBi was moved from (0,0) to (1,1) to (2,2) in the FOV. These locations correspond to angular distances of 3.5°, 2.1°, and 0.7°, and 1.4, 0.8, and 0.3 beamwidths, respectively, from the nearest desired terminals. For each location, the directive gain was measured at points near the null, and the resultant gain profiles are plotted in Figure 4-2. The plot shows the gain profile of the null around each interferer. The horizontal axis is the angular distance from the interferer in degrees. (Positive values denote distances from the null toward desired terminals; negative ones, distances from the null away from desired terminals.) The vertical axis represents the directive gain in decibels. Although the shapes of the respective profiles are different, the cases where the interferer is located at (0,0) and (1,1) achieved the desired 40-dB average discrimination. From Figure 4-2 it is noted that when the inteferer is furthest away, the pattern has a much broader null. While the discrimination is approximately 30 dB in 1° with user-interferer separation

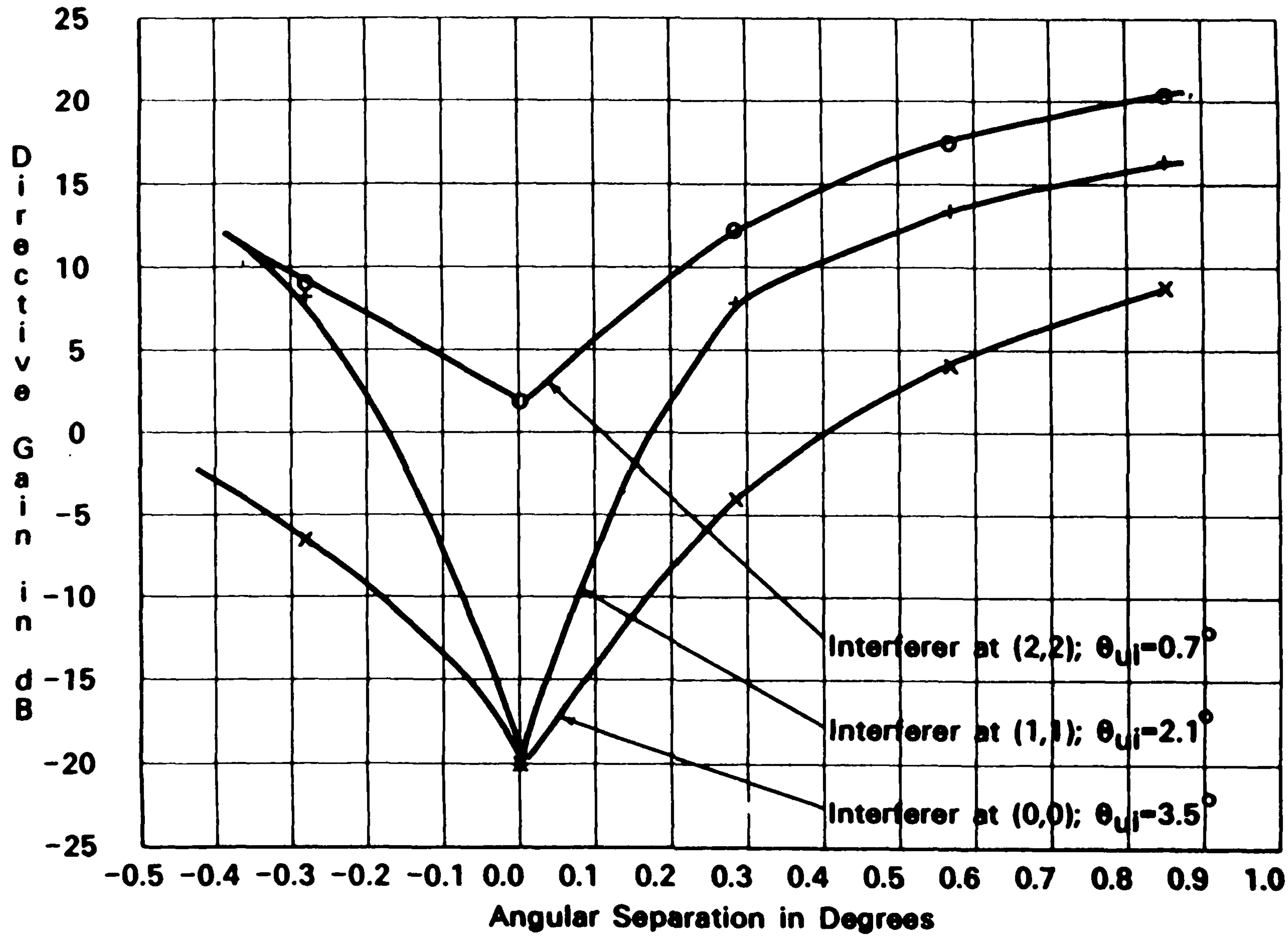

Figure 4-2. Effect of Interferer Location on Null Shape

$\Theta_{ui}=3.5^{\circ}$, it is about 38 dB in 1° with $\Theta_{ui}=2.1^{\circ}$. The reduction in achievable discrimination, which is indicated as the user-interferer separation is reduced, shows the resolution limitation of the given MBR antenna aperture. With $\Theta_{ui}=0.7$, the desired discrimination was not achieved; the overall discrimination was only about 20 dB/$^{\circ}$. However, the desired directive gain of 20 dBi was achieved at 0.85 degrees from the null, closer to the null than the other two cases with greater Θ_{ui}. In each of these cases, the algorithm achieved the desired user gains, but to do so as Θ_{ui} decreased, the algorithm sacrificed null depth and discrimination.

4.4 SPECIFYING A NULL REGION

The previous cases all specify a single point as the interferer location. A more desirable pattern, however, would be one in which the null is broader to account for open-loop pointing errors mentioned in Section 4.1. To give a broader null, a region of null points can be specified. This is the purpose of the next set of experiments.

These experiments focus on the scenario with a single interferer at (2,2) (an angular separation of 0.7°), and they examine the effect that specifying a null region has on gain pattern shape and discrimination. The scenario of Figure 4-1 was used with a single interferer, a (2,2) (an angular separation of = 0.7°). The directive gain of the desired terminals was chosen to be 20 dBi with a point null of -20 dBi. Two examples were considered: one with a single point null and another with a null region. The null region consists of all the points adjacent to the interferer location and is shown in Figure 4-3. The effect of specifying a region, rather than a single point, on the gain profile is shown in Figure 4-4. Specifying a null region created a deeper null and provided greater average discrimination between the desired terminals and the interferer. To find the average discrimination, the

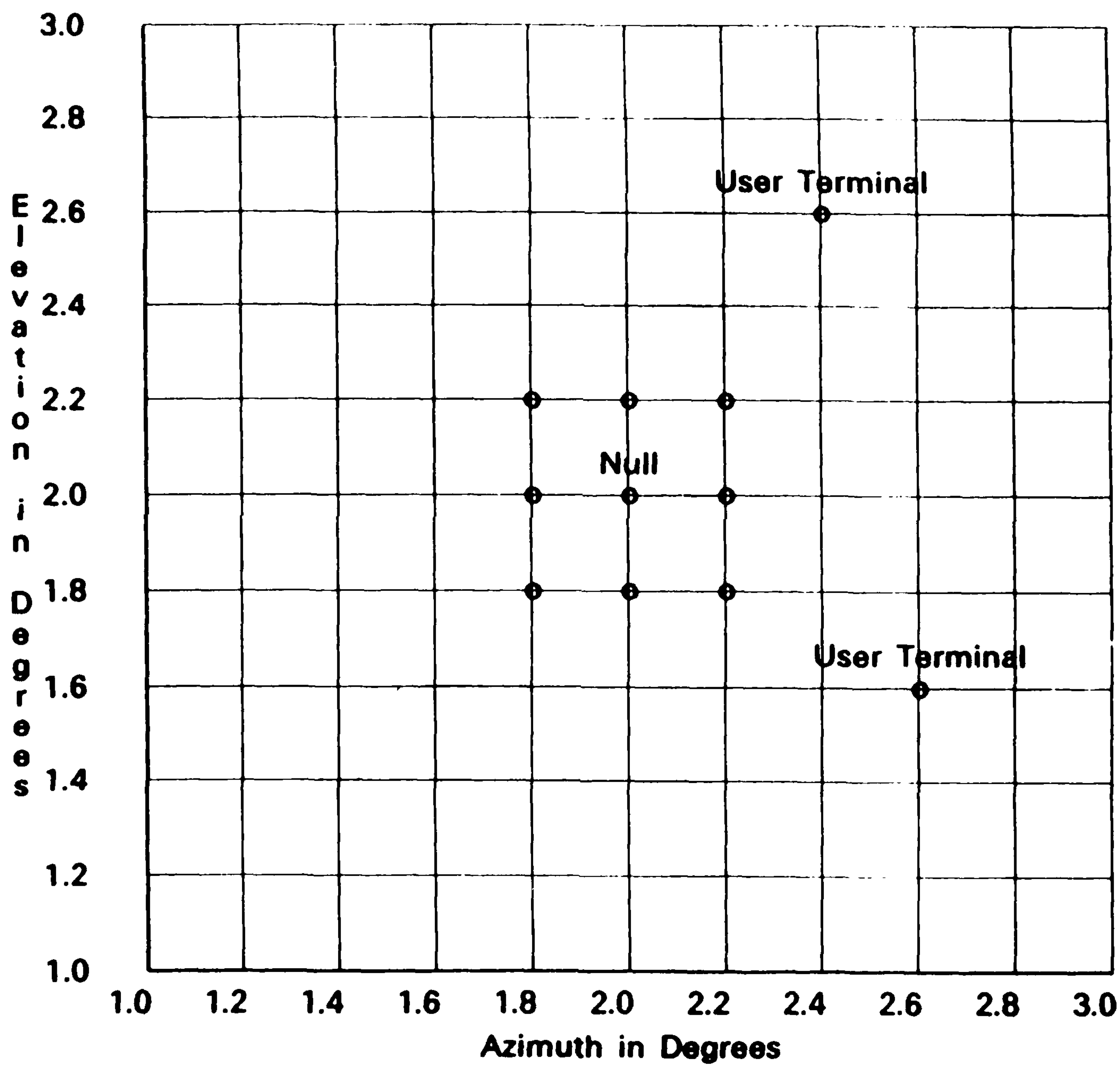

Figure 4-3. Null Region Used with Experiments

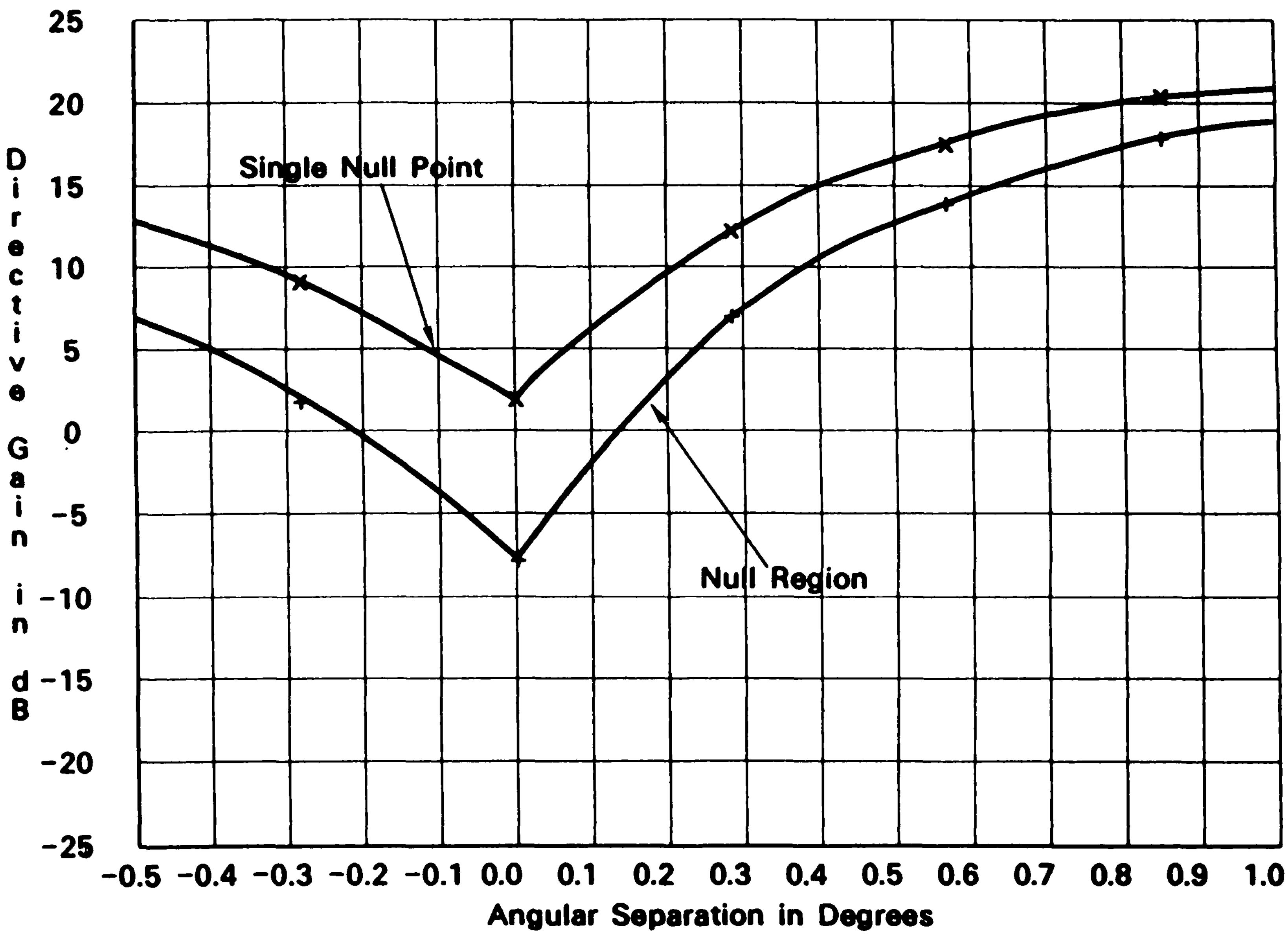

Figure 4-4. Use of a Null Region to Affect Null Shape

average difference in gain (in decibels) between each user location, and the interferer was computed as follows:

$$(\Delta G)_{dB} = \frac{1}{n}\sum_{k=1}^{n} [(G_{d_k})_{dB} - (G_i)_{dB}] .$$

where ΔG = the average discrimination

n = the number of user terminals (20)

G_{dk} = the resultant voltage gain at the k-th user location

G_i = the resultant voltage gain at the interferer location

While the average discrimination with a single-point null was 17.8 dB, it was 27.4 dB with the null region of Figure 4-3. The single-point case had the advantage of achieving the desired gain at a smaller distance from the interferer. The null-region achieved the desired 20-dBi gain at a distance greater than 1^{o}, whereas the single-point achieved 20 dBi in less than 0.85^{o}. Therefore, specifying a null region provides a deeper null and greater overall discrimination than a single null point.

4.5 WEIGHTING OF TERMINAL AND NULL LOCATIONS

All previous examples used an equal weighting [B = Identify Matrix in equation (2-6)] for all terminal and null locations. The next set of experiments examined the effect of weighting on null shape. The experiments used a desired directive gain of 20 dBi for terminals, -20 dBi gain for the interferer, and a single-point null. Unless otherwise specified the nominal weighting of each location is unity.

Three weighting schemes were considered in the experiment. The first scheme was an equal weighting for all locations, the second scheme weighted the interferer location with a factor of 10, and the third example weighted the

interferer with a factor of 100. Gain profile curves for the three different weighting schemes are plotted in Figure 4-5. Although there is little difference among the three curves beyond 0.3° from the interferer, the null was clearly deeper with increased weighting.

Figure 4-5 shows only the gain near the null; it does not show how the overall difference between the user and the interferer gains was affected. Table 4-1 presents the values of the average discrimination for each of the weighting schemes, and it shows that the average discrimination increased as the weighting increased. The predominant effect of weighting the interferer location was to increase the null depth without changing the directive gain to nearby locations. To determine whether the increased null depth was achieved by lowering the average gain to the desired terminals, the average gains were also computed. These results are also presented in Table 4-1, and there was no significant difference among the three cases. Therefore, the depth of the null did not affect the average gain to the desired terminals.

Table 4-1. Average Discrimination Versus Interferer Null Weighting

Interferer Weighting	Average Discrimination (dB)	Interferer Gain (dB)	Average Terminal Gain (dB)
1	17.9	1.9	19.9
10	32.5	-12.8	19.7
100	39.0	-19.2	19.8

Comparing the effect of weighting a single interferer location and using a null region (of multiple interferers), the former provided greater null depth and more discrimination.

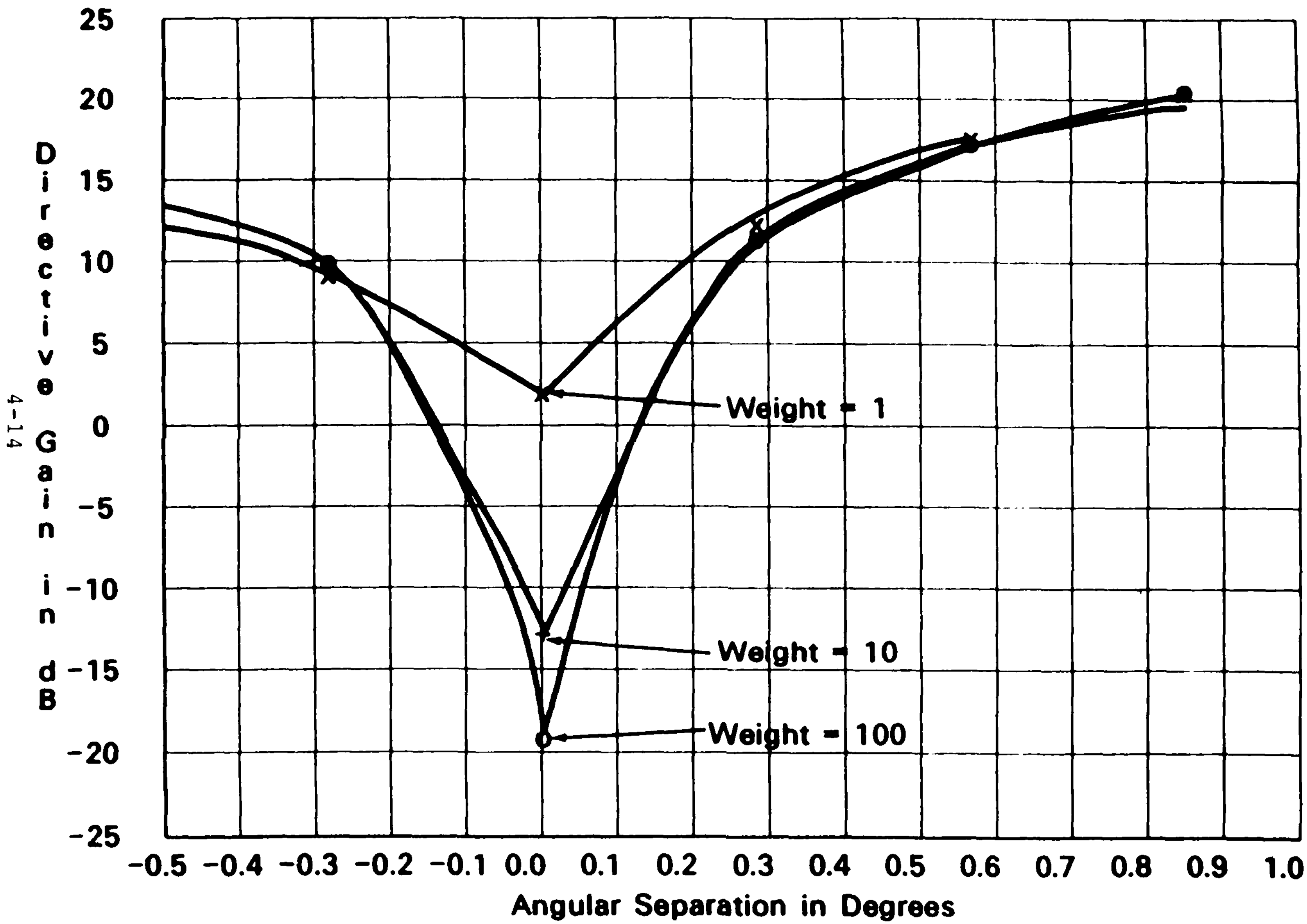

Figure 4-5. Effect of Interferer Weighting on Null Shape

While both methods may be used to increase null depth, a null region tends to pull down the gains beyond 0.3°, whereas weighting does not. That is, use of nulling regions broadens the null width at the expense of a gain reduction to the user locations.

4.6 COMBINED EFFECTS

To this point, the discussion has focused on how a null region and weighting individually affect the shape of the null. This section considers the effect if both techniques are used simultaneously.

These experiments use the basic scenario with a single interferer at (2,2). The same null region shown in Figure 4-3 is specified with a desired directive gain of -25 dBi, and the gain to users in 25 dBi. All locations had unity weighting except the interferer location at (2,2), which was assigned weighting factors of 1, 10, and 100. Gain profiles for the three different weighting schemes are plotted in Figure 4-6. Although there is little difference among the three beyond 0.3° from the interferer location, the depth of the null was increased with increased weighting. Table 4-2 presents the values of the average discrimination for each of the schemes and shows that the value increased as the weighting increased. The predominant effect of weighting the interferer location was to increase the null depth without changing the directive gain to locations beyond 0.3°. To determine whether the increased null depth was achieved by lowering the average gain to the desired terminals, the average gains were computed. The average directive gain to users are also presented in Table 4-2. There is no significant difference in average gain noted among the three cases. Therefore, an increase in null depth did not sacrifice gain to the desired terminals.

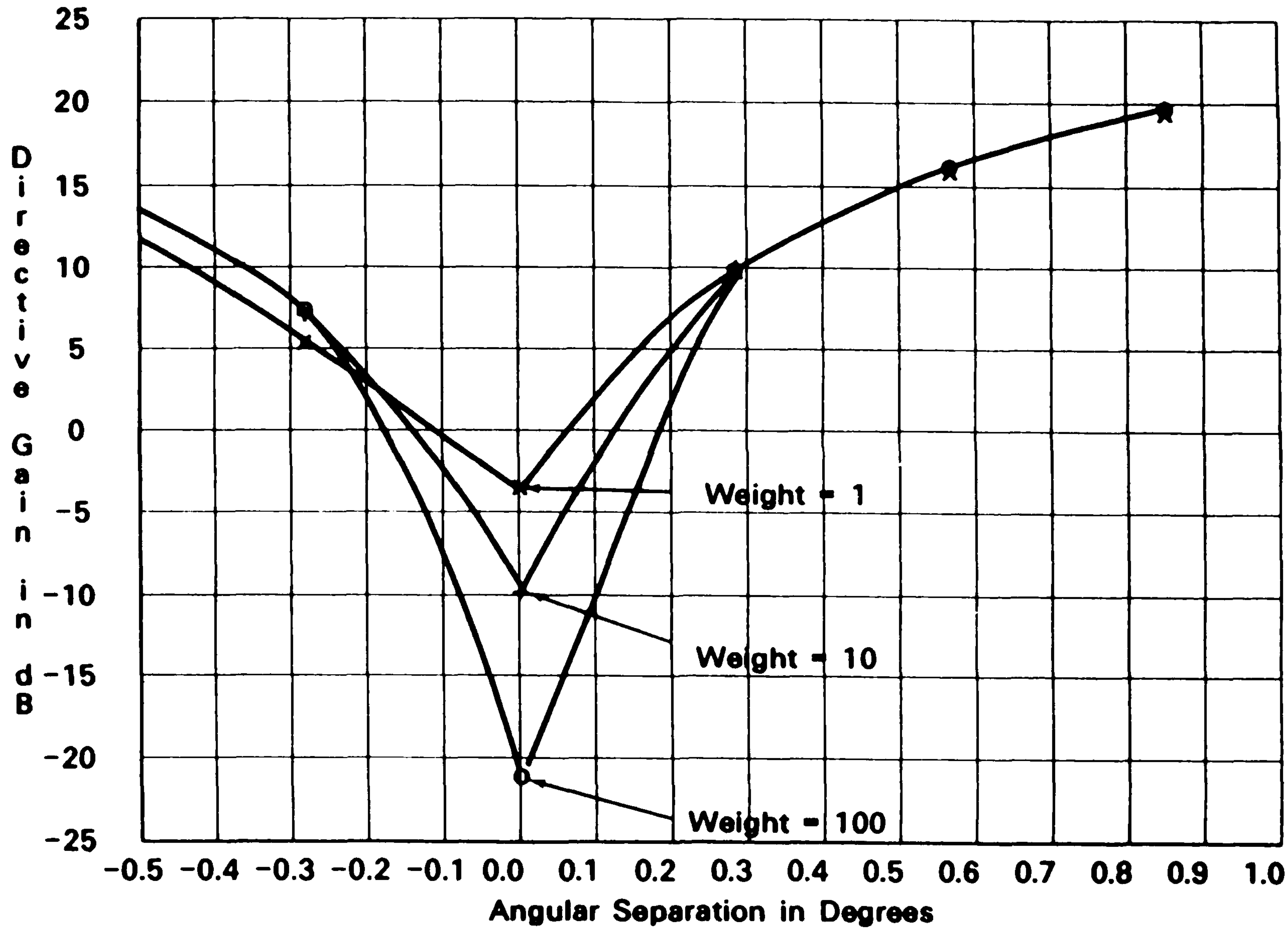

Figure 4-6. Effect of Weighting and a Null Region on Null Shape

Table 4-2. Average Discrimination with a Null Region and Different Weighting

Interferer Weighting	Average Discrimination (dB)	Interferer Gain (dB)	Average Terminal Gain (dB)
1	25.2	-3.5	21.7
10	31.7	- 9.8	21.9
100	42.9	-21.1	21.8

4.7 COMPARISON NULLING CRITERIA

The experimental results discussed in previous sections have shown that by increasing the relative importance (weighting) of selected locations to achieve required directive gains, and by adding specified gain location to extend the desired gain region, different resultant gain patterns and null region shapes can be produced. The characteristics of these different pattern may be exploited to meet specific scenario requirements.

This section compares three patterns produced for a particular scenario, and identifies the characteristics and trade-offs associated with each. Three cases with the scenario of Figure 4-1 and a single interferer at (2,2) (an angular separation of = 0.7°) are considered.

1. An unweighted interferer specified by a single-null point, 40-dB desired discrimination, and 20-dBi desired terminal gain.

2. A weighted (weight=10) interferer specified by a null-region, 40-dB desired discrimination, and 20-dBi desired terminal gain.

3. A weighted (weight=100) interferer specified by a null-region, 50-dB desired discrimination, and 25-dBi desired terminal gain.

The gain profiles of these three cases, each involving a single interferer at (2,2), are plotted in Figure 4-7. Although these three cases have nearly the same gain at 1° from the interferer, the shapes of the nulls generated are quite different. If it is more important to generate a pattern with a smooth rise from the null (to avoid sensitivity to satellite platform pointing errors, or movement in the satellite position versus time), the first pattern might be chosen because it provides the smoothest rise by limiting discrimination. The second pattern might be selected to give a smooth null with moderate discrimination. If a sharp, deep null were desired, the pattern of case three might be chosen. Consequently the algorithm provides great flexibility in generating the null shape.

4.8 CONCLUSIONS

Initial results shown that excellent performance, expressed as mean square error between desired and achieved radiation patterns, can be achieved within the theoretical resolution of the MBR antenna aperture.

4.9 LIMITATIONS OF THE MBR ALGORITHM

There are several limitations of the proposed MBR algorithm. One shortcoming is that the algorithm does not consider overall system performance in generating the beam weights. The algorithm simply provides an LMS match to some specified directive gain pattern by a functional minimization technique. However, the algorithm does not consider such large-scale system parameters as the composite network data throughput rate or the carrier-to-noise density ratio, C/N_0 for all links in the network. Thus, if the input desired pattern is physically non-realizable due to antenna aperture size limitations, the algorithms will simply provide a LMS fit to the required input gain pattern. The resultant gain pattern

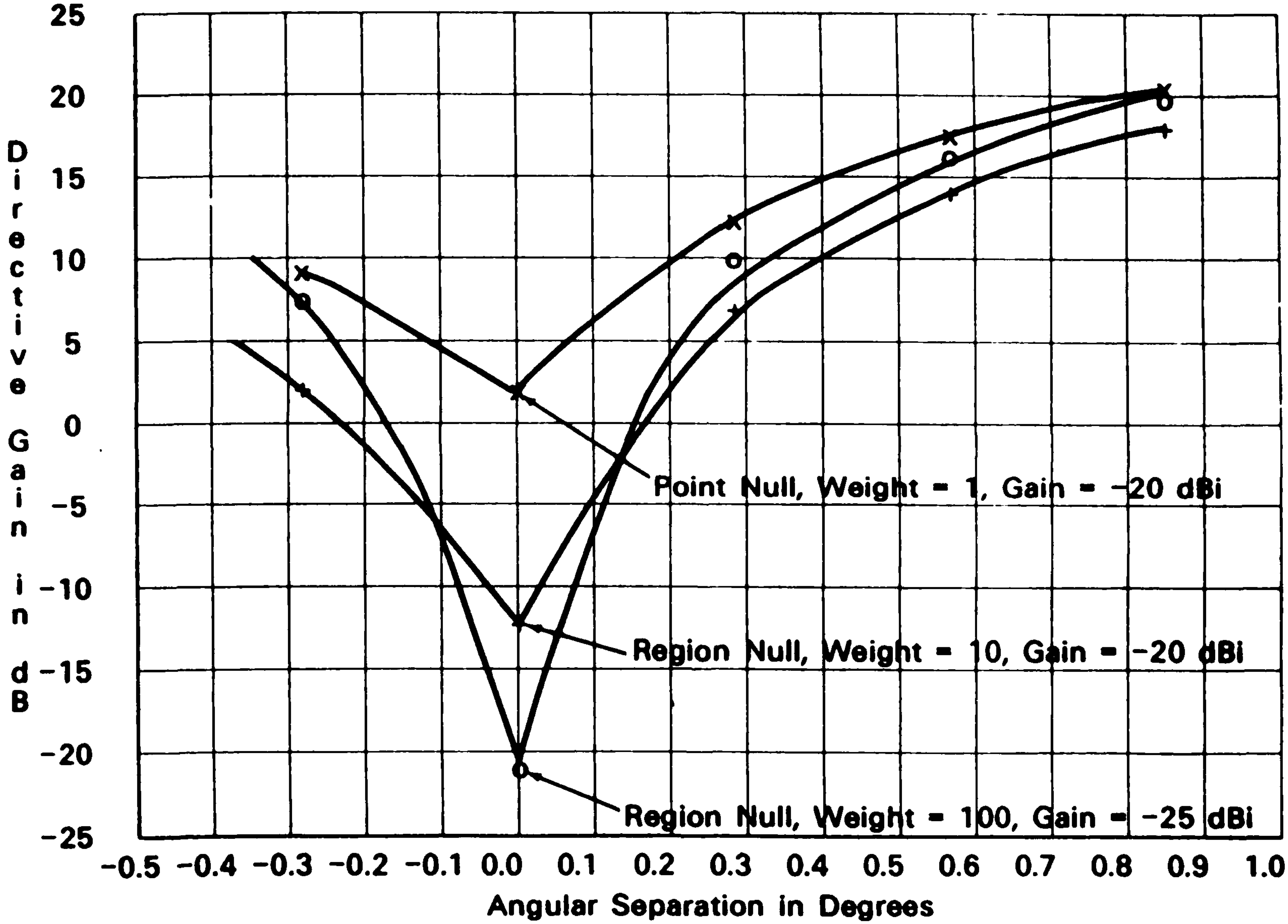

Figure 4-7. Comparison of Different Null Shapes

can, however, be used to provide guidance as to what "new" gain pattern should be requested.

There are also limitations induced by the format of the antenna data itself. One such limitation is that frequency dependent effects are not considered in the current analysis. The performance of each singlet beam is also a function of the frequency at which the antenna is excited, but singlet data measurements used here correspond to a single frequency (at the center of the band of interest). If the antenna frequency response is relatively broad (as with the DSCS III 61-element MBR), the resultant antenna patterns are expected to be quite accurate. However, if the antenna patterns are highly frequency dependent, then the technique examined here would have to be extended.

Another limitation due to the antenna data is that the terminal locations can be specified to only within 0.2° in azimuth or elevation. This limitation arises because the singlet antenna data are provided for points 0.2° apart. This means that terminal locations specified in the scenario data and the actual location of the terminal may be differ by $\pm 0.1^{\circ}$. If there is a significant difference in the gains achieved at the two point, the algorithm may not actually perform as well as the results suggest. To overcome this limitation, interpolation between measured samples in the singlet data could be used.

The results may also be optimistic because the algorithm does not consider the effects of beam weight quantization. The algorithm assumes that a continuous set of beam weights is allowed, but the DSCS III MBR has six-bit quantization on the in-phase and quadrature beam weight components. The effect of quantization generally diminishes the gains to desired

terminal, increases the gain to interfering terminals, and changes the phase throughout the FOV. Future research should consider the effect of beam weight quantization.

One limitation previously mentioned is that the algorithm considers only the desired directive gain, but not the desired phase response at a given terminal location. The ability to specify the phase response would be particularly useful in investigating such techniques as phase tapering to shape null regions. The B matrix weighting technique described in Reference 5 and introduction of spatial fields described in Reference 5 provide benefits analogous to the effects of phase tapering. An exact comparison of the two methods, however, would require further research.

In spite of these limitations, the algorithm provides a practical technique to find beam weights for the DSCS MBR. Most of the preceding limitations may be overcome with reasonable modifications to the algorithm and by interpolation between measured samples of the singlet data.

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(U) The purpose of this task was to evaluate the utilization of the DSCS Operational Control System (DOCS) and to provide version release test support for the DSCS Network Planning Software (DNPS). This report also examines the development of multiple beam antenna (MBA) algorithms to calculate beam weights that provide minimum mean square error (MSE) performance between desired and actual gain contour patterns.

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Mr. John Cormack

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